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## Direct Instruction In Mathematics: Issues For Schools With High Indigenous Enrolments: A Literature Review

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## **Direct Instruction In Mathematics: Issues For Schools With High Indigenous Enrolments: A Literature Review**

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*Abstract: Direct instruction, an approach that is becoming familiar to Queensland schools that have high Aboriginal and Torres Strait Islander populations, has been gaining substantial political and popular support in the United States of America [USA], England and Australia. Recent examples include the No Child Left Behind policy in the USA, the British National Numeracy Strategy and in Australia, Effective Third Wave Intervention Strategies. Direct instruction, stems directly from the model created in the 1960s under a Project Follow Through grant. It has been defined as a comprehensive system of education involving all aspects of instruction. Now in its third decade of influencing curriculum, instruction and research, direct instruction is also into its third decade of controversy because of its focus on explicit and highly directed instruction for learning. Characteristics of direct instruction are critiqued and discussed to identify implications for teaching and learning for Indigenous students.*

In recent years in Australia the achievement gap between non-Indigenous, economically advantaged students and Indigenous students at risk of school failure—for instance, those of lower socio-economic status have become a primary concern in Australian education (De Bortoli & Thomson, 2010; The Productivity Commission, 2009; Thomson & Hillman, 2010). The analysis of data from the OECD Program for International Student Assessment from 2000-2006 (De Bortoli et al., 2010) reveals large gaps between reading and mathematics scores for Indigenous students who are economically disadvantaged. Indigenous students were found to perform at a substantially and statistically lower average level in reading, mathematical and scientific literacy than their non-Indigenous peers, across all PISA cycles (De Bortoli, et al., 2010). Indigenous students, who had poor attendance at school for long periods of time and changed schools regularly, were found to underperform in mathematics compared to students who spend more time on mathematical tasks. The findings showed that “disciplinary climate, absence during primary school, elaboration strategies, socioeconomic status, self-efficacy in mathematics, self-concept in mathematics, gender and preschool attendance were found to significantly influence mathematics performance (p. 88).”

Many authors have pointed out that these results have forced schools to address the education of underserved and underachieving students (Flemming, 2009; Masters, 2008a; Masters, Rowley, Ainley & Khoo, 2008b); with schools turning their attention to at risk students because Federal and State Government accountability policies, such as the National Assessment Program for Literacy and Numeracy [NAPLAN] requirements, ensure that states test their students uniformly, regardless of school location, student demographics, or student

disabilities. Further, states are to expand and improve their data collection procedures about student, school and district academic achievement so that it is available to parents and community members through education sites such as *My School* (Australian Curriculum Assessment and Reporting Authority, 2010; Hanewald, 2011). The intended consequences of this policy is that instructional approaches are now being trialled and advocated to improve the education performance of Indigenous and non-Indigenous students. One such approach currently being trialled in schools in Queensland with high Indigenous populations is Direct Instruction (cf. Flemming, 2009). In order to understand this approach the paper reviews the claims advanced by proponents of direct instruction and the practices devised for this approach to mathematics learning without substantial comment. It will then critique the practices and provide evidence in support of this approach.

### **Direct Instruction: The discussion**

There has been strong debate amongst the polity and populace for schools with high Indigenous populations to adopt a Direct Instruction [DI] approach to teaching reading and mathematics to address this gap (cf. Abbott, 2009; Chilcott, 2010; Devine, 2010; Flemming, 2009; Leigh, 2009; Pearson, 2009). Variously described as “a radical learning program”, “an education revolution”, “a root-and-branch reformation of indigenous schooling” and “explicit instruction”, the trialling and adoption of DI in Indigenous schools is intended to improve instruction which, in turn, improves the educational outcomes of their students (Flemming, 2009; Pearson, 2009).

Pearson (2009, p. 52) makes a distinction between explicit and implicit learning and between students who grow up in “Western educated classes” and Indigenous students who have not grown up in the same environments. He argues that Indigenous students have not “had the same opportunity to implicitly learn the “hidden structure” (my words) of learning in this tradition”. Further, Indigenous students “by virtue of their backgrounds, [are] over-represented in the bottom quartile” (p. 53) compared to their mainstream counterparts. It is this over-representation that Pearson aims to turn around, that is, Indigenous disadvantage in employment, housing, and life expectancy will improve because of the “high-quality education” that DI proponents are aiming for (Pearson, 2009, p. 60-61). Recognising this aim, DI has emerged as an approach to: enhance the learning of Indigenous students who are experiencing failure, and; close the educational gaps faced by these students. Closing this gap is what is strongly advocated by DI proponents (cf. Becker & Engelmann, 1973; Mong & Mong, 2010; Rowe & Stephanou, 2007a).

### **Project Follow Through**

Direct Instruction emerged from one of the most comprehensive large scale, longitudinal educational investigations in the USA of direct instructional approaches, Project Follow Through (Becker & Engelmann, 1973). This study was conducted from 1967 to 1976, with follow-up work continuing to 1995 (cf. Becker et al., 1973; Engelmann, 1970, 1991; Watkins & Slocum, 2004). It reviewed twenty different approaches to educating disadvantaged students from Kindergarten to Year 3 and incorporated seventy thousand school children and one hundred and eighty schools (Adams & Engelmann, 1996). Of all the approaches, direct instruction was found to contribute most significantly to closing the gaps faced by students identified as at-risk of school failure (Adam et al., 1996; Ellis, 2005; Engelmann, 1970; Engelmann & Carnine, 1991).

With DI, the focus is on academic objectives and is premised on the belief that every student can achieve academically if they receive adequate instruction (Becker et al., 1973). It contends that well designed instruction, informed by the Direct Instructional Systems in Arithmetic and Reading [DISTAR] begins with the “skills the children bring to school and to build on them at a faster rate than would occur in a more traditional setting” (p. 1). A student taught at the “normal” rate would remain behind “his” peers, thus, faster-than-normal rate procedures must be applied. Such procedures

1. require a far greater number of responses from the child,
2. are adjustable to individual rates of progress,
3. use programmed materials which teach essential concepts and operations required for future tasks,
4. systematically use reinforcement principles to insure success for each child,
5. utilize novel programming strategies to teach the general case (usually called intelligent behaviour) rather than focusing on specifics (usually called rote behaviour, or rote memory). (Becker et al., 1973, p. 1)

The DISTAR program for arithmetic is designed to teach the problem solving operations to ensure that students know how an operation works and why they are using it (p. 10).

Arithmetic facts are then taught after they can use the operations. Finally, they learn “several fundamental laws or rule of mathematics” (p. 3). The curriculum then is highly structured and engineered for success and efficient learning (Grossen, 2004). It provides “behaviourally based instructional activities that are directly related to increasing achievement in basic academic skills” (Jones & Southern 2003, p. 4). More simply, it has been described as the teacher helping students to become aware of what they need and are to learn, and how they are to use this new knowledge (Stotsky, 2006, p. 6). For its proponents, it is a prime and proved example of an “effective teaching methodology” (Stone, 2002, p. 45).

Learning is said to be accelerated through the provision adequate staffing (Becker, et al., 1973). For example, one teacher and two teacher aides are required for Levels 1 and 2 classrooms of 25 students and one teacher and one teacher aide for Levels 3 and 4 classrooms of 25 students. A progress tester is assigned for each 150-200 students who tests the students on a 6 week teaching cycle. A local teacher supervisor is assigned for every 200 students to supervise the implementation and progress of the program. Parents are expected to be involved in the program with training in the Levels so that they can then become teacher aides or assistants. “Parents can be taught testing for the continuous evaluation of the progress of the children (p. 4).

Classrooms are set up so that the teachers and teacher aides work “in booths (for sound control with groups of 4 to 7 children” (p. 3). Students are rotated through such groups and activities where they are required to work on their own, or as a total group. Students in Levels 1 and 2 spend 30 minutes for small group instruction in mathematics. Students in Levels 3 and 4 are provided with fifteen minutes of instruction followed by thirty minutes of self-directed practice in workbooks that are later checked by the teacher.

However, the analysis of the implementation of the DISTAR program in 1973 showed that the program had mixed results (Becker et al., 1973). For example, Kindergarten starting “poor children” who were near or above grade level, lost ground. Grade 1 starting children were “a little below the grade level”. These results were attributed to arithmetic not being taught much and when it was taught by teacher aides and, the focus was more on reading rather than arithmetic. The results indicated that by Grade 3 Kindergarten starting children made gains whilst Grade 1 starting children fell short. Modifications were to be implemented with the expectations that results would improve. Other factors that influenced

the results in the program included the role of training and supervision was not focused on for a variety of reasons, for example, sites not liking research which “might” withhold services from their children. Attempts at correlating teacher performance and child outcomes were unsuccessful because of difficulties with establishing controls by having teachers taped in middle and low groups and teaching a common task.

Despite the mixed results of the program in 1973, it is now in its fourth decade of influencing curriculum, instruction and research, direct instruction is also into its fourth decade of controversy because of its focus on explicit and highly directed instruction for learning (Hirsch, 2002; Magliaro, Lockee & Burton, 2005). To understand the positions of proponents and opponents of DI the next section responds to some of the practices identified in DI, including: instructional style, communication and interaction, textbooks, pace of instruction, grouping of students and assessment. These will then be followed by a full critique.

### **Direct/Explicit Instruction and Practice: The research**

A number of inter-related practices that are characteristic of instruction-based mathematics education can be identified from the literature on direct instruction. For example, direct instruction is intended to provide a highly structured, rigorous and effective form of teaching. Students are to focus on the teacher who presents well-designed and scripted lessons at a fast pace. Rehearsal, memorisation and testing of content are central. The students, who are grouped by ability, are expected to respond as a group and or individually. The teacher who provides feedback and correction to the students initiates the interactions. Key elements of this formulation include rehearsal, clear didactic communication, a sequenced program of instruction and practice, brisk pacing of instruction, streaming by ability and objective assessment. These practices are now discussed in turn to identify their claimed influence on student participation and engagement in learning mathematics.

#### *Instructional Style*

Direct instruction has been advocated as a highly structured approach that uses explicit teaching and well scripted lesson plans (Adams et al., 1996; Rumph, et al., 2007b; Stone, 2002). It focuses on “small chunks deliberately isolated from the complexities of actual situations” (Hirsch, 2002, p. 63). A step-by-step direct and explicit approach is said to benefit students because of the limitations of the working memory. During instruction, the teacher’s task is to ensure meaningful attention by students to what is to be learned using whatever methods are available. Rehearsal, also referred to as rote learning (Mayer, 2002) or drill, is seen as one means to this end.

There is a strong argument, well supported in the literature on direct instruction, that rehearsal or rote learning (Mayer, 2002) is necessary for the retention of what is learned (cf. Hirsch, 2002; Rumph, et al., 2007a). Directly and explicitly teaching what is to be learned requires students to rehearse what they have learned. This is done at a very fast pace, rather than through drawn out explanations of new concepts (Becker, 1992). Typically, what is remembered is determined by how often it has been rehearsed (Hirsch, 2002).

In this framework, retention is understood as the “ability to remember material at some later time in much the same way it was presented during instruction” (Mayer, 2002). Rehearsal or rote learning provides the means by which students retain what is learned and then transfer it to solve problems or to learn new content. Paradoxically, this accommodation of knowledge and skills to the uniqueness of the student is claimed to be more effective in improving student learning (Stone, 2002) than if they were allowed to discover ideas on their own (Evers & Walberg, 2001). Similarly, direct instruction that is result-orientated and uses

methods such as rehearsal and rote learning is claimed to boost student self-esteem through success in learning (Stone, 2002).

It should be noted, however, that direct instruction has different characteristics depending on the grade level to be taught (Stein, Silbert & Carnine, 1997). Direct instruction in the primary grades or for students who experience difficulties in the middle year grades, is characterised as more structured and teacher-directed. The teacher asks more questions, provides immediate feedback and corrections and praises the students (Stein, et al., 1997). In the upper grades of primary, group work is decreased and independent work increases (Stein, et al., 1997). Similarly, if instruction is intended for students who are “average or above average” (p. 3) and in the middle years of schooling, there is a strong emphasis on student-directed independent work (Stein, et al., 1997) integrated with didactic instruction (Jones & Southern, 2003, p. 1).

### **Communication and Interaction**

Direct instruction is a teacher-centred pedagogy that focuses on clear didactic communication. In this approach, “educational effectiveness for all students is crucially dependent on the provision of quality teaching by competent teachers who are equipped with effective, evidence-based teaching strategies that work” (Rowe, 2006, p. 105). The teacher, who possesses sound mathematical content knowledge, is seen to be the expert who passes this knowledge onto students via direct instruction, rehearsal and rote learning. It is the teacher who tells the students what they need to know and learn (Hirsch, 2002; Stotsky, 2006). Hence classroom interactions are largely initiated by the teacher, that is, they are didactic (Jones & Southern, 2003). Here, “instruction is delivered with a standard format in which the teacher secures the students’ attention, prompts their overt responses during acquisition, requires overt and unassisted responses to demonstrate mastery, and follows acquisition with systematic practice” (p. 5).

Interactions generally do not involve student-to-student interactions, although these are not discounted (Jones & Southern, 2003). Findings from the TIMSS observational study, indicate that if teachers are to instil a deep understanding of mathematics in the students they teach, they must provide explicit explanations that students understand (Siegel, 2006). In this framework, then, teachers are expected to possess a thorough knowledge of the content and processes of mathematics. They require an understanding of the underlying general principles of mathematics to guide their application effectively and to support student learning (Hirsch, 2002). If these requirements are met, instruction will succeed when concepts are conveyed accurately through “faultless communication” (Engelmann & Carnine, 1991, pp. 2-3).

The intention of faultless communication is to lead students directly to a “single interpretation of the instruction, and ideally that same instructional communication would work for all learners” (Engelmann et al., 1991, p. 3). Here, the students’ responses to the instruction are seen to provide precise information about their learning. In this approach, what a student learns is seen as a function of the communication received and the characteristics of the student and what she or he brings to the situation. In short, if faultless instruction fails to achieve the intended communication, the instruction is not considered to be at fault. Rather, the failure of instruction indicates that there is a problem with the student and her or his behaviour. In this event, the teacher is required to observe and analyse the student’s behaviour and provide appropriate remediation. The intention is not to blame the student for her or his failure to learn, but rather to analyse the behaviour of the student in order to “correct deficiencies in the learner’s cognitive repertoire” (p. 3).

A key characteristic of direct instruction is “unison responding” (Stein et al., 1997, p.

9). Unison responding increases student attention. When used correctly, it is considered an “effective tool for engaging students in learning, as well as for monitoring students’ progress” (p. 9). However, for teachers who include unison responding in their classrooms, this requires specific presentation skills, including the use of “signals” (p. 9).

Signals are cues given by the teacher that indicate to students when to make a unison response (Stein et al., 1997). The effective use of signals is claimed to enhance the participation of all students, “not just the high performers who, if allowed, tend to dominate the lower-performing students” (p. 9). Their use apparently avoids the problem of reducing the amount of practice that low performing students receive.

To signal a unison response, the teacher is required to give directions, provide a thinking pause, and cue the response (Stein, et al., 1997, p. 9). When using directions, the teacher “tells the students the type of response they are to make and asks the question” (p. 9). The duration of the thinking pause is determined by the length of time that the lowest-performing student takes to find the answer. “If one student is unable to answer or takes longer to answer, the student is either provided with more individual practice, or placed in a lower-performing group” (p. 9). Carefully controlling the thinking pause is crucial for maintaining student attention and successful learning experiences. It is generally signalled by the teacher who says, “Get ready!” just before the thinking pause (p. 9). The get ready prompt is to indicate to students when to expect the signal to respond. The cue to respond may include a click of the fingers, clapping the hands, touching the board or any action that indicates a cue.

Proponents of direct instruction propose that effective teaching is didactic, communication is directed from the teacher, and its success is contingent on their ability to communicate with clarity. Advocates of faultless communication, unison response and signals argue that this type of instruction supports student learning of mathematics. They claim that it provides adequate learning and practice opportunities for all students. Within this teaching model, the source of activities and tasks are drawn heavily from textbooks because of their tendency to provide scripts on how to instruct.

### **Direct Instruction Programs**

To this point, attention to mathematics classroom interaction has focused on oral communication from the teacher who follows a highly structured sequence to instruct students. Such communication is strongly directed and informed by heavily scripted written instruction programs. The programs provide that highly structured sequence for teachers to follow as they instruct their students. Significantly, in addition to textbooks for student practice and independent work, there are teacher presentation textbooks—textbooks for teachers that provide scripts on how to instruct students about mathematics (Bessellieu, Kozloff & Rice, 2001; Flemming, 2009; Stein, et al., 1997). The latter are characterised as scripts for teachers that provide clear, explicit, concise teaching strategies to assist student learning (Farkota, 2003). The content to be learned is that which is provided in the teacher textbooks.

These scripts provide teachers with explicit pre-tested examples and sequences that relieve them of programming (Farkota, 2003; Kenny, 1980; Rowe, 2007b). As concepts and strategies are taught, the script provides “step-by-step transition from explicit teacher-directed instruction to completely independent work” (Kenny, 1980, p. 17). Independent work refers to the “mass practice” of exercises that students are required to complete without teacher assistance at a time designated by the teacher (Stein, et al., 1997, p. 25). Students are never assigned independent seat work if they have not demonstrated success during

supervised practice (Stein, Kinder, Silbert & Carnine, 2006).

Transitions to independent work are achieved through guided practice and the teacher prompting the next steps (Stein, Silbert & Carnine, 1997). Systematic prompts are used to draw student (Kozloff, 1999)

attention to signals (“Listen to this.”); help craft ongoing actions in a more competent fashion; or help direct attention to the results of past actions (“Did the solution turn pink?”). Prompts include: 1) **gestures** (a teacher points to a trouble spot in an equation); 2) **suggestions**; 3) **instructions** (“Pour acid INTO water, not water into acid.”); 4) **highlighting** features of the setting (e.g., crucial information in a text is in italics); and 5) **models** (“Try it like this.”). (p. 1)

Prompting in this sense assists students with efficiently maintaining and transferring the new skills and knowledge acquired (Jones, et al., 2003; Stein, et al., 1997). Textbooks and worksheets serve similar functions and are described in similar ways in a direct instruction program. Worksheets provide prepared sequenced material for each of the different concepts to be taught. Their purpose is to enable the teacher to coordinate the related teaching activities and memorisation exercises. This allows the teacher to monitor easily the progress of the students’ performance and mastery.

In a typical example from one such program (Stein, et al., 1997), the worksheets are divided into two parts for practising number facts. The top half provides practice in new and previously learned facts. The bottom half of the worksheet includes the facts from the new set, each written twice, along with previously introduced facts, each appearing just once (Stein, et al., 1997, p. 88). The pace at which this work moves is critical in this process.

### Pace of Instruction

In a review of the literature on time management (Kelly, et al., 1999), pace has been described in two related dimensions. The first refers to curriculum pacing. It is concerned with the rate of progression through the curriculum. The second dimension is lesson pacing. This refers to the pace at which the teacher conducts lessons (Kelly, et al., 1999).

In this framework, the key to a sound mathematics learning program that uses textbooks and or worksheets is to maintain student focus throughout the learning process. However, this focus has been shown to be dependent on how the teacher introduces the concepts orally and questions the students (Farkota, 2003). The pace at which this is done should be easy enough to accommodate all the students but also brisk enough to ensure that they have no time to be bored (Farkota, 2003; Kinder & Carnine, 1991; Sangster, 2006). The National Numeracy Strategy in British schools (Kyriacou, 2005a) has also advocated a brisk pace for mathematics lessons. Teachers were expected to commence lessons in a quick and lively way with a mental/oral whole class activity, and students were expected to respond quickly. The intention of this part of the lesson was to arouse the students’ interests, making this part of the lesson enjoyable and motivating (Kyriacou, 2005a).

Brisk lesson pacing has been shown to be important for student achievement. In studies of classroom teacher performance (Heward, 2003; Kelly, et al., 1999; Wyne, Stuck, White & Coop, 1986), it was found that a brisk pace in lessons improved the learning of most students, including those considered low-achievers. Student attentiveness and participation was stimulated and more content was covered (Wyne, et al., 1986). Content coverage, however, was found to be dependent on the level of difficulty of the lesson. Here, an effective lesson was one that permitted a high rate of student involvement and success. Difficult and poorly presented lessons could not be learned at any pace (Kelly, et al., 1999; Wyne, et al., 1986).

Significantly, fast-paced instruction was seen as necessary for the progress of students with learning difficulties (Heward, 2003; Kame'enui & Simmons, 1990).

In short, fast-paced lessons and instruction were claimed to provide more learning opportunities by the teacher, more student responses and accuracy per lesson and improved on-task behaviour. The students' learning was said to be accelerated because of the effect of a brisk pace on student achievement (Berliner, 1984; Heward, 2003). Indeed, it is claimed that when a brisk pace is done effectively, teachers cover more content on a daily rate. In consequence, they do have time over a year to consolidate and review the content covered.

### **Grouping of Students**

Homogeneous grouping of students is influential in maximizing and benefiting student learning (Engelmann, 2002; Watkins & Slocum, 2004). Here homogeneous grouping describes the practice of using general measures of performance—and thus by inference, 'ability'—in mathematics to allocate students to an appropriate group level in the classroom. These small groups are graded from low through to high ability. A similar process of ability grouping occurs across classes and grades (Marchand-Martella, Blakely & Schaefer, 2004). Such grouping is seen as necessary for direct instruction and cognate approaches (Marchand-Martella, et al., 2004). DI proponents argue that this enables individuals and groups of students to get maximum benefit from effective instruction. In this process of classification, they are to be grouped according to the level "where they have the necessary prerequisite skills and have not yet mastered the objectives" (Watkins & Slocum, 2004, p. 40). Here, the skills to be taught should be closely aligned with what students have already learned but just beyond their current level of understanding (Watkins, et al., 2004). In this way, it is argued that teachers can instruct the groups and attend to the learning needs of individual students in those groups.

According to a report on balancing approaches for teaching students with learning difficulties (see Ellis, 2005), this type of small group instruction is effective for providing opportunities for the teacher to direct and attend to students and provide them with feedback about their learning. In this way, those students who are achieving can progress more quickly, whilst those who are not can receive the necessary support and practice to further their learning (Ellis, 2005). However, if groups are heterogeneous—comprised of students who know the content to be learned and those who do not—the latter are less likely to learn that content in the allocated time. This will particularly be the case if the instruction is targeted at those who have the prerequisite skills and are ready to move on. In this instance, the effectiveness of the program of instruction for accelerating all students is considerably reduced (Engelmann, 2002; Kauffman, Landrum, Mock, Sayeski & Sayeski, 2005).

Students placed appropriately are those who "perform at 70% correct on any skill or content introduced for the first time" (Engelmann, 2002, p. 1). This percentage indicates that they are ready to master new content. However, if a student performs at fifty percent correct on the same tasks, that student is considered to have too much content to learn in the allocated time (Engelmann, 2002). This student will therefore be changed to a lower grouping that matches her or his needs (Engelmann, 2002; Kauffman, et al., 2005).

Students do not enjoy learning mathematics when they have not been well matched or grouped to their prior knowledge or ability to learn and perform (Kauffman, et al., 2005). They are more likely to do whatever it takes to withdraw or exclude themselves from that instructional situation. This may be because the instruction requires understanding and performance that is too difficult for the student, thus resulting in embarrassment, disruptive, inattentive behaviour and anxiety (Kauffman, et al., 2005). Alternatively, it may be that the

instruction is too easy for the student and requires them to review what they have already mastered and the likely result is boredom and inattention.

In short, homogeneous student grouping is claimed to benefit all students in their learning. Providing the instruction is effective, the needs of students will be appropriately addressed. However, if they have not been appropriately matched and or grouped to their level of performance, effective learning is less likely. This is because they are trying to learn at a level that is well beyond their current knowledge and skills. Testing students to allocate them to the appropriate group apparently works to alleviate these consequences.

### **Assessment**

The allocation of students into homogeneous groups is largely informed by the students' performance on placement tests (Watkins & Slocum, 2004). These 'objective' tests are generally designed to measure student performance on subject matter and encompass a range of specific skills needed for progress and successful learning (Rumph, et al., 2007b; Watkins & Slocum, 2004). Their results are used to indicate each student's starting place in a program of instruction (Stein, et al., 1997; Watkins, et al., 2004).

Objective testing is also referred to as summative testing. Summative testing measures pre-existing knowledge. Put another way, it attempts to summarise a student's learning at a given point in time (Larson & Keiper, 2007). Although assumed to have negative consequences, supporters of direct instruction argue that it can have positive effects if it is aligned closely with instruction that is "deeply criterion-referenced, incorporating the intended curriculum, which should be clearly salient in the perceived assessment demands" (Biggs, 1998, p. 107).

Timed tests are used in direct instruction. The teacher sets a specified time that is realistic for the students. A short time, "a minute or two", (Stein, et al., 1997, p. 89) is provided for students to study the test that is located at the bottom half of their worksheets. The teacher then instructs them to get ready (Stein, et al., 1997, p. 89).

The teacher tells the students how much time they have and to start. At the end of the specified time, the teacher says, "Stop", has the students trade papers, and reads the answers. Students are to mark all mistakes, write the total number correct at the top of the page, and then return the worksheets to its owner. (p. 89)

The results are then recorded by the teacher. Depending on the performance of the students, the same worksheet will be presented to students again in the next lesson, if less than three quarters of the class performed satisfactorily. This system of testing claims to allow the teacher to link activities similar to the test and utilise memorisation exercises. It is also claimed that it allows for precision and fluency in basic skills (Wu, 1999) and easy monitoring of student performance and progress (Stein, et al., 1997).

In short, through testing and practice, rapid and effortless performance of basic skills "frees attention for thinking about complex operations" (Snider & Crawford, 2004, p. 213). In this framework, then, basic skills are seen as forming the foundation for conceptual understanding. Their acquisition provides the stepping stones to higher-level skills (Snider & Crawford, 2004). Testing enables teachers to monitor student mastery of basic skills so that they can move to more complex tasks.

### **Research Evidence Supporting Direct Instruction**

The proponents of the direction approach draw on research conducted over the last forty

years provides strong support for the effectiveness of a direct instruction approach in schools. The evidence, largely quantitative and statistical, has been used to justify its practices for improving mathematics achievement for students, including those with learning difficulties.

Support for direct instruction was also provided in an early review of research conducted in Australia (Lockery & Maggs, 1982). This review argued that, when used appropriately, direct instruction was effective in supporting both mainstream students and those with learning difficulties. Further Australian studies of effective intervention strategies for students with learning disabilities in mainstream primary school have recently concluded that the findings

are entirely consistent with those from a large body of evidence-based research that indicates superior effects of initial *direct instruction* and *strategy instruction* approaches on student learning.” So what made the difference to students’ learning and achievement progress for those in the *intervention* schools? Simply, teachers in the *intervention* schools were **taught how to teach** via *direct/explicit instruction* teaching methods – informed by findings from local and international evidence-based research. (Rowe, 2006, p. 13).

The Third Wave project and the Intervention Project Working Out What Works have shown that much of what is currently implemented in schools for mainstream children and children with learning difficulties is grounded in findings from evidence-based research (Rowe, 2006; Rowe & Stephanou, 2007a). In particular, the most effective instructional strategies for students with learning difficulties were found to be a combination of aspects of direct instruction and strategy instruction.

Other studies have addressed the effect of instruction-based approaches on student performance in mathematics. For example, in a study of the application of fractions, decimals and percentages, fifty-eight students from Years 5 and 6 were randomly assigned to either a direct instruction group or a constructivist group (Grossen & Ewing, 1994). The results demonstrated that students in the direct instruction group performed significantly higher than those students assigned to the constructivist group. Another study addressed the effects of direct instruction on the performance in fractions of thirty middle years school students from twelve to fourteen years of age, who had learning difficulties in mathematics (Flores & Kayler, 2007). The results demonstrated the statistical and educational significance of the program.

In a comparative study of teacher-student interactions in mathematics conducted in Russia and England, different patterns of interactions were noted (Wilson, Andrew & Below, 2006). These findings seem to justify a more traditional approach over a more reform-based one. The Russian lessons focused on mastery of factual and procedural knowledge of mathematics content through repetition of previously taught procedures that reinforced algorithmic approaches, whereas the English lessons emphasised individual ideas and justifications of responses to a task. That is, the Russian context prioritised performance using prescribed approaches, whereas the English context placed importance on students applying reasoning to new mathematical situations and ideas. The study highlighted the difference between the English approach that asked students to think for themselves about mathematics which they might not have grasped, and the Russian approach that motivated the students as it built their capability, confidence and enjoyment of mastery of mathematics. The Russian approach supported the students’ interest and performance in mathematics (Mullis, Martin & Foy, 2005).

Other recent studies have shown the benefits of direct instruction for student progress in mathematics. One Australian study examined Year 7 students’ self-efficacy in mathematics using a direct instruction model (Farkota, 2003). This study of nine hundred and sixty-seven

school students across fifty-four different classrooms from 2001-2003 found that direct instruction was significant for improving students' self-efficacy, and in consequence for improving their performance on mathematics tasks. In short, proponents of direct instruction claim they have a solid base from which to argue because of the theory and consistent evidence-based statistical research that informs and drives it (Farkota, 2003; Hempenstall, 2004; Rowe, 2006). Despite the considerable research support for the direct instruction-based approach, there is also a body of literature that provides a substantial critique.

### **A Critique of Direct Instruction**

A substantial critique, typically informed by a reform perspective, has been levelled at the traditional and behaviourist approaches to mathematics teaching and learning. There are two dimensions to this critique. At the level of theory, it is largely driven by liberal-progressive and cultural studies assumptions about human nature and society (Beane & Apple, 1999; Dewey, 1916). At the corresponding level of practice, the argument is typically based on ethnographic accounts, interviews and case studies of teachers and students, schools and classrooms. It is in this second level, the level of practice that much of what follows is set. It is important to note that this critique is often directed more at what was observed in classrooms than the ideal formulations of, for example, direct instruction. Here, too, Bernstein's (1990) insight into the ways in which practices at the workforce differ from their initial formulation is pertinent. That is, what is observed and called into question in classroom practice may be somewhat removed from an ideal situation.

Certain practices central to direct instruction approaches to mathematics education have been identified in a number of reform-based studies of mathematics classrooms (cf. Boaler, 2002; Schoenfeld, 2006; Wood, Shin & Doan, 2006). These practices were found to inhibit student engagement in learning mathematics. They had a substantial influence on how the students identified themselves as mathematics learners, to the extent that some students reported that they could not do mathematics. The practices specifically critiqued include, a didactic teaching style, memorisation and rote learning; emphasis on teacher to student communication and interaction; emphasis on learning mathematics from a textbook; a common fast pace of work in mathematics classrooms; streaming students by ability; and pen-and-paper assessment. This selection is now critically examined from a reform perspective, that does not support this approach.

## Instructional Style

A didactic teaching style is associated with a long standing tradition of mathematics education, in which mathematics teachers, as the authoritative possessors of the requisite mathematical knowledge, transmit approved parts of it to those who do not possess it, their students (Scherer & Steinbring, 2006). In this transmission or ‘sender-receiver’ model of education (Scherer, et al., 2006), the receiver is passive and their function trivialised (Wertsch, 2001). Their task is about extraction—to find the meaning in the words, take it out of them, and get it into their heads (Wertsch, 2001). Such an approach, with its emphasis on “processes of repetition, replication and reproduction of received knowledge” (Kalantzis, 2006, p.17) seems ill-suited to the reality of an increasingly knowledge-based and innovation-based economy.

In the transmission framework, and in contrast to those expectations, mathematical knowledge remains fixed and eternal; it is taught, not discovered (Wertsch, 2001). The teacher provides information, demonstrates procedures, and determines whether the necessary knowledge has been acquired through questions that require rehearsal and recall of the relevant facts or procedures (Kyriacou, 2005b; Kyriacou & Goulding, 2006). Hence opportunities for students and teachers to discuss together not simply how, but why the procedures work are necessarily limited. Teaching, learning and mathematical knowledge continue to be viewed in isolation rather than as three interactive elements of a “didactic triangle” (Scherer, et al., 2006, p. 159).

Moreover, if mathematics is seen as the transmission of knowledge with minimal or no discussion, it follows that it is about rote learning, rehearsal, memorisation and isolation (cf. Kalantzis, 2006). In primary and secondary classrooms that reflect an instructivist approach, an overemphasis on memorisation of procedures has been found to occur instead of conceptual understanding (Cooney, 2001; D'Ambrosio & Harkness, 2004; Wood, et al., 2006). Typically in these classrooms, superficial memorisation rather than fluency and flexibility (Wood, et al., 2006) is the natural concomitant to instructing and lecturing students (Cooney, 2001).

Thus, as students move through the grades of schooling, limited opportunities are provided for defending answers and justifying their mathematical thinking. Their learning of mathematics becomes largely procedural with minimal opportunities for inquiry and constructing an identity as a successful mathematics learner (D'Ambrosio, et al., 2004). A focus on the transmission of mathematical knowledge rather than learning how to inquire into mathematical ideas with understanding (Carpenter & Lehrer, 1999) means that most students receive little or no practice at participating in solving mathematical problems (Schoenfeld, 1994). In mathematics classrooms that adopt a traditional approach, students learn that there is only one correct way to solve mathematical tasks—usually the rule most recently demonstrated by the teacher (Schoenfeld, 1994). However, step-by-step instructions for working through rules that emphasise speed and accuracy have been shown to limit any form of knowledge construction or inquiry (Brown, Askew, Rhodes, Denvir, Ranson & Wiliam, 2003).

In short, in the critique of a didactic style of teaching, the following points have been made. Classroom interaction is largely a one-way process from the teacher to students. When confronted with this style of teaching, learners have limited opportunities to inquire and investigate mathematics. Memorisation, rehearsal and rote learning are inevitable concomitants of this process. The assumptions underpinning this approach have been brought into question, in particular, that mathematics knowledge can be passed or handed over from the teacher to the student (Scherer, et al., 2006; von Glaserfeld, 1991). A more detailed examination of teacher and student interactions within a traditional approach to the teaching

and learning of mathematics is now appropriate.

### Communication and Interaction

Traditional classroom communication is characterised by “teacher dominated classroom talk, most learners silent for most of the time” (Kalantzis, 2006, p. 17). That description seems appropriate for many mathematics classrooms where the teacher is the authority on mathematical knowledge, while students by definition lack that knowledge. Consequently, classroom communication is directed and controlled by the teacher. It is initiated by the teacher, directed to a student or students, who respond, and the teacher then evaluates their response. Unless sanctioned by the teacher, and then seldom, student-to-student interaction is not legitimised (Cooney, 2001; Lampert, 1998).

The consequences are significant. Because communication is largely one-way and student to student interaction is inhibited, students’ opportunities to discuss and apply the language of mathematics in social interaction are constrained (McNair, 1998). They most likely learn a restricted and narrow version of mathematics that has come largely from the teacher. Hence also, when they are expected to reason their solutions to mathematical exercises and logically support their conclusions, they do not have the language or the experience to do so because of limited opportunities to interact and communicate at a conceptual level of understanding (McNair, 1998).

More recent international comparisons of interactions between teachers and students reported in the *Knowledge and Skills for Life: First results from the OECD Programme for International Student Assessment* (PISA) 2000 (OECD, 2001) indicate that the type of interactions between teachers and students is statistically significant when associated with student success/failure and performance. It was found that traditional one-way interaction from the teacher to the student did not support student achievement in mathematics because it provided limited opportunities to talk about mathematics.

Indeed, one-way communication appears to be a central aspect in teacher-student interaction across international boundaries. In *Teaching Mathematics in Seven Countries: Results from the TIMSS 1999 Video Mathematics Teaching* (Hiebert, et al., 2003), teachers were identified as talking more than students “at a ratio of at least 8:1 words” (p. 4). While the typical intention of teacher talk is to support students with learning mathematics, it can have the opposite effect on students (Begehr, 2006). The consequence is that they are denied opportunities to describe the content to be learned in their own words, to reflect what they are learning and have learned and what they need to learn in the future. Their efforts to understand the mathematics content are reduced to disjointed fragments without explicit links made while opportunities diminish for them to interact genuinely in and with the overall content. Instead, they are guided along a narrowly defined path that does not grant them time to express their own thoughts about their learning or engage with and use the mathematical language (Begehr, 2006). In consequence, they are less likely to develop and learn the rich body of language associated with mathematics and use it when talking about their learning.

In summary, in this critique of traditional mathematics, one-way communication from teacher to student contributes to limited opportunities for student exploration or inquiry in mathematics. Because of these limited opportunities, students are less likely to access or use the language of mathematics to express their mathematical ideas. Typically, their strategies remain in their heads, hence their teachers have limited understandings of what students know and can accomplish. Rather, what is more likely to be known is those who can succeed and those who do not—which is further emphasised when textbooks are a central feature of classroom teaching.

## Instruction textbooks

In her portrayal of traditional education, Kalantzis (2006) noted the subordination of the teacher to the textbook as the legitimate authority of subject knowledge: “syllabi, textbooks and disciplines command, and the teacher is the mouthpiece. . . . Teacher as medium for the syllabus, textbooks speaking singularly for the discipline” (p. 170). In what follows, drawing on the relevant research and literature critiquing this practice, the dominance of the textbook in instruction-based mathematics classrooms is investigated and its consequences for mathematics learning addressed.

Textbook usage features significantly in many primary and secondary mathematics classrooms. Typically, learning mathematics involves doing mathematics from a textbook (Shield, 2000). For example, according to *The TIMSS 1999 International Mathematics Report* (Mullis, et al., 2000), textbooks and or worksheets of some kind were found to be used in ninety percent of lessons. More than fifty percent of the students who participated in the TIMSS study reported working on worksheets or textbooks in class and that the use of the board to present mathematics was “extremely common” (p. 20).

In secondary mathematics classrooms, work from a textbook is an individual process and is separated from other curriculum areas (Askew, 2001; Nickson, 2002). In consequence, students learn that mathematics is about solving routine exercises that are broken into discrete steps and isolated from their daily experiences. Furthermore, and as noted previously, they learn that they cannot communicate mathematically because of the narrowly defined path they are guided down with its limited vocabulary often only possessed by the teacher (Nickson, 2002).

Confirming Kalantzis’s (2006) observation above, a research study of textbook use in classrooms found that authority is invested in the textbook authors and not classroom teachers (Romberg & Kaput, 1997). That is, the expert knowledge of the teacher was deliberately subjugated to that of the textbook. Because of that process, the teacher was able to camouflage his [sic] role as authoritarian, thus eliminating student challenges of authority. (Weller, n.d., cited in Romberg & Kaput, 1997, p. 358). For example, when textbooks were used in classrooms, teachers used the term, they—as in ‘Do it as they show you in the book’—to imply that the authors of the textbook knew what students needed to know (Romberg & Kaput, 1997). In this way, teachers reduced any likely challenges to their authority from students, potentially shifting responsibilities for teaching and learning to the authors. Consequently, the textbook and authors were used as a substitute for the teaching and learning process.

This substitution was found to be more likely in classrooms where there was heavy reliance on textbooks to demonstrate how something was done, and where learners were expected to work separately though on the same exercises to reproduce what the textbook had shown them (Romberg, et al., 1997). Thus teachers were released from the responsibilities of planning work and considerations of student differences in learning (cf. Kalantzis, 2006).

An international comparative study of textbook use indicated a similar dependency on their use in primary school classrooms (Harries & Sutherland, 1999). This dependency was associated with teachers relinquishing responsibility for lesson planning to the textbooks. That is, the textbooks provided a routine and time-saving approach for teaching mathematics, and so they also informed what happened in mathematics lessons from one day to the next (Harries, et al., 1999). Consequently, mathematics was discussed in relation to exercises or chapters in textbooks rather than focusing on the teaching and learning of the concepts of mathematics (Harries, et al., 1999). Meaningful conceptual interaction and inquiry into

mathematical concepts were less likely because getting through the content of the textbook became the driving factor. In consequence, how learning shaped students' developing knowledge and understanding was discounted.

The use of textbooks raises further concerns about the audience for which they are intended. A study of three high school and college textbooks indicated that the same text was provided to students of varying mathematical knowledge and understanding (Raman, 2004). This one-size-fits-all approach negated meeting the requirements of students at different levels of learning. For students who experienced difficulties with reading and mathematics, learning was inhibited because of the amount of reading required to solve the problems (Gagnon & Bottge, 2006). Consequently, such students are excluded from learning about mathematics, thus reinforcing what they may already know about themselves—that they cannot do mathematics and do not belong in the mathematics classroom.

While textbooks intended for students of 'low ability' offer an alternative to this one-size-fits-all approach, they bring fresh problems in that they work to construct their users as lower in ability (Dowling, 1998). In this case, the teacher draws on the textbook to use with particular students, but in so doing, has assessed them as being low ability. This assessment is also associated with other labels for these students, for example, they are students who have short attention spans, and are unable to follow and cope with complex instructions and tasks (Dowling, 1998).

Further investigations of textbooks and the way they are used in classrooms indicates that the activities in the texts were often poorly thought out and written, focusing more on repetition and review, with concepts covered superficially rather than for conceptual understanding (Lithner, 2004; Remillard, 2000; Shield, 2000). For example, in a study of mathematical reasoning in calculus exercises in textbooks, the exercises focused mainly on the surface properties of questions (Lithner, 2004). That is, the rules and definitions were described in the texts at the expense of the mathematical properties involved in reasoning. Similarly, while superficial tasks may have their place in textbooks, textbook authors need to provide a balance between these exercises and more complex ones where students were required to consider the mathematical properties of the exercises. If not, the risk is that students might develop weak conceptual understandings and superficial and ineffective strategies for solving tasks. A further recommendation is that while textbook authors do not have complete authority over how textbooks were used in classrooms, writers of textbooks need to talk to teachers about the mathematics and pedagogical ideas underpinning the texts (Remillard, 2000, Shield, 2000).

Yet what reasonable alternatives to a substantial reliance on textbook use are there when, as Kalantzis (2006, p. 17) observes, the traditional classroom formulation involves "thirty or so students facing one teacher", with "all thirty such learners regarded for practical purposes as the same [and with] one-size-fits-all curriculum and pedagogy". Any resolution involves changing or rejecting some element or the other in this formulation.

In summary, the authority of the textbook in traditional mathematics has been addressed and its implications have been explored. When the textbook serves as the teacher surrogate, it has the potential to exclude students from effective mathematics learning and gaining mastery of mathematical concepts they need to support them in their future schooling. When the textbook is used in a one-size-fits-all approach, the consequence for many students who, for whatever reason, cannot do the work, is failure. However, when low achieving students are provided with textbooks suited to their level, their status as 'low ability' or failures is further confirmed. In this 'catch 22' situation, how textbooks are used has the potential to increase the gap between those who can do mathematics and those who cannot or who cannot muster interest in what passes for mathematics in these books. When considered together with the common pace at which all students are expected to work through

the textbook, and the prescriptive nature of communication in the traditional classroom, the mathematics textbook is a powerful tool that contributes to sorting students along the lines of success and failure in mathematics.

### Pace of Instruction

A fast common pace of work in mathematics classrooms is a further consequence of what Kalantzis (2006, p. 17) described as the “one-size-fits-all curriculum and pedagogy”. Here pace refers to both the limited duration of time taken or allowed to undertake specified work and to develop conceptual understanding in mathematics lessons and the underlying pressures for curriculum delivery within a specified period—a lesson, a term or a year. While the pace at which conceptual understanding occurs varies for individual students, moving the class along at a common pace when working through a textbook is the accepted practice in many traditional classrooms and a taken-for-granted corollary of a prescribed curriculum. The pace at which students are expected to learn as they work through the textbook or workbook exercises has implications for their future success or failure in what they come to know and understand as mathematics.

The pace of a lesson has been shown to lead to tensions between the desirability of student understanding and a duty to maintain the attention and interest of the remainder of the class (Wilson, Andrew & Below, 2006). For example, in studies of English and Russian mathematics lessons, short durations of time for interactions predominated in English lessons because of the need to get through the prescribed content and to maintain the attention of the class. Hence they were found to be largely tentative listeners instead of active inquirers. In consequence, mathematics learning was largely focused on what the teacher did and said, rather than what the students learned and understood (Wilson, et al., 2006). This was likely to be at the expense of slowing down and analysing how a response was obtained rather than getting through quantities of content (Office for Standards in Education, 2001) that was superficially taught and learned. In the Russian context, however, students were expected to listen attentively to their teachers and more time was allowed for individual students to demonstrate their oral or working responses to tasks on the board with the class listening and watching.

The negative effects of pace are particularly evident in classrooms that promote competitive learning where the focus is on speed and accuracy in mathematics. Students have been shown to demonstrate a dislike of mathematics because they perceive themselves as unable to keep up with the competitive demands of the classroom (Ulep, 2006). This stress on speed and accuracy reinforces students’ perceptions that success in mathematics is attributed to ability, thus having a negative effect on lower achievers (Kyriacou, 2005a). The consequence for many students is induced anxiety (Kyriacou & Goulding, 2004) and learned helplessness (Ulep, 2006). As a consequence of their experiences of forced pace in traditional mathematics, rather than knowing what mathematics to learn, how and why they need to learn it and where they need to go in terms of their learning, students learn that mathematics is about success and failure.

A further negative consequence of an emphasis on speed during mathematics lessons is that students watch, copy or guess answers rather than thinking more deeply about the questions asked and the mathematics involved (Kyriacou, 2005a). This process, in part, may be associated with what students come to know as mathematics—right or wrong answers rather than inquiry. Students who need more time to think have been left behind in terms of their learning because they do not have time to discuss their responses. Low-attaining students have been found to be vulnerable to public exposure and less likely to participate

because they could not keep pace (Kyriacou, 2005a; Myhill, 2002). However, the risk of slowing the pace too much has been found to fall short of the need to cover the year's curriculum content that is assumed by the next year's curriculum (Balfanz, MacIver & Byrnes, 2006). Consequently, in a 'catch 22' situation, in fact, less curriculum was found to be covered.

In findings from studies of British and Australian secondary students' experience of learning mathematics, differences in pacing were found between upper and lower-streamed classes (Boaler, 2002; Ireson, Hallam & Hurley, 2005; Zevenbergen, 2001). For example, British students in the upper-streamed classes experienced the mathematics curriculum delivered at a rapid pace (Boaler, 2002). Opportunities to explore, analyse and investigate mathematical concepts were limited because of the need to get through the content. However, for students in lower-streamed classes, the pace was slowed, with less curriculum content covered, more repetitive work, less discussion and analysis (Ireson, et al., 2005) together with prescribed work that was considered easy (Boaler, 2002). Much like their British counterparts, lower-streamed Australian students were found to be taught a restricted curriculum at a slower pace (Zevenbergen, 2001).

In summary, issues relating to pace in mathematics classrooms and in curriculum coverage create tensions for teaching and learning mathematics, which, in turn have implications for what students come to know as mathematics and the extent of their participation. When the focus in the classroom is on getting through the curriculum content whilst at the same time maintaining student interest and engagement, less time is spent on inquiring into mathematics. Thus, the mathematics taught and learned is more inclined to be fast paced at a superficial level that emphasises accuracy rather than a deeper level of understanding. Consequently, what some students come to know and learn about mathematics is that it is about success and or failure, a view that has been shown to contribute to learned helplessness and or anxiety. The pace of mathematics classrooms and the extent to which mathematics concepts are addressed have the potential to contribute to sorting students along the lines of those who can keep pace and those who cannot. In consequence, students are more likely to be grouped according to their ability to keep pace and other measures such as pen-and-paper testing.

## **Grouping of Students**

Streaming has been described in various ways. For example, in the USA it is described as tracking and differentiation (Linchevski & Kutscher, 1998), while the UK uses the terms set and ability grouping (Boaler, Wiliam & Brown, 2001; Hallam & Ireson, 2006; Ireson, et al., 2005). In Australia the most frequently used terms are streaming and ability grouping (see for example, Zevenbergen, 2001). Whatever the terminology, streaming influences and shapes how students identify themselves as participatory mathematics learners and their social roles within secondary mathematics classrooms, their interactions with teachers, and their attitudes towards school and schoolwork (MacIntyre & Ireson, 2002).

The streaming of students by ability has been shown to be influential on student success and achievement in secondary mathematics (Ireson, et al., 2005; Wiliam & Bartholomew, 2004). In studies of streaming in secondary schools, the class that students are allocated to has been shown to have a significant influence on how well they will do in mathematics (Wiliam & Bartholomew, 2004). Thus, ability grouping has a small positive effect on high attaining students (Ireson, Clark & Hallam, 2002), while the opposite applies to students in the low sets (Wiliam, et al., 2004). There was a range of differences between these two groupings, including the type of work covered, the teaching they were given, and what was

expected of them. Further it was better to be streamed into higher classes than lower classes because their differences contributed to widening the achievement gap across an age cohort (Wiliam, et al., 2004).

As with pace, success in mathematics has been at the expense of students finding out about what they should know and how they should learn it (Hallam & Ireson, 2005; Wiliam, et al., 2004). What has been shown to be significant is that this practice was adjusted according to the groupings of students. For example, in the higher streamed groups, the curriculum content was covered at a fast pace, whereas in the lower streamed groups, the opposite was the case. In the lower groups, student work was undemanding and copied from the chalkboard (Wiliam, et al., 2004). Students were provided with more structured work that covered less of the curriculum topics (Ireson, et al., 2005). These kinds of experiences were found to negatively influence the students in the high and low streamed classes (Zevenbergen, 2001).

The pressure to compete and perform and to keep pace with content delivery during lessons has been identified as causing stress among students in the higher streamed classes (Boaler & Wiliam, 2001). In these classes, the students were unable to learn the meaning of the mathematics because there was minimal time to inquire, question and explore mathematical topics (Boaler, 2002; Boaler et al., 2001). Less time was spent on responding to individual students' needs (Boaler, Wiliam & Brown, 2001).

In mathematics more than any other subject, more rigid views are held that the subject must be taught sequentially and certain concepts and skills mastered before others are introduced (Gamoran & Weinstein, 1998). Mathematics teachers have been similarly reluctant to move away from streaming students because of their rigid conceptions of the subject and their belief that students could be taught more effectively when they were divided into groups of similar ability.

In summary, ability grouping has been found to be detrimental to student progress in mathematics. It has substantial implications for students' future opportunities. That is, students in the lower ability classes are less likely to be exposed to the mathematical content of the high ability classes, thus limiting their opportunities. Students in the higher ability classes, on the other hand, experience stress because of the need to perform and keep pace with the content delivery. The practice of ability grouping has significant implications for what students come to know as mathematics. This knowledge is further reinforced through pen-and-paper testing.

## Assessment

The ubiquitous pen-and-paper testing is a logical concomitant of streaming students by ability. Several studies (Black & Wiliam, 1998; Shen, 2002; Tierney, 2006) have shown how summative assessment such as pen-and-paper testing continues to dominate in classrooms. Summative assessment in this instance refers to a judgement that encapsulates pieces of evidence to a given point (Taras, 2005). The dominance of this type of assessment is not only a product of external standardised assessment requirements, it is also the consequence of an "assessment revolution" (Broadfoot & Black, 2004, p. 19) that prioritises quantitative data for "delivering transparency, accountability and predictability" (p. 19).

For example, Glass (2008) well documents the accountability movement in public education that has stemmed from the Bush administration's No Child left Behind [NCLB] policy, indicating that there is a troubling connection between the accountability movement and the changing ethnic composition in America's schools. He contends that there is a link between accountability and ethnicity. In systems where there is highly punitive

accountability, those who are politically “weak and vulnerable” can be found. Further, he argues that such measures have been implemented to “embarrass education and discredit public education” (p. 203).

The incentives to perform well on tests are high for teachers, students and school administrators (Glass, 2008). For students, pass or failure is about promotion to the next grade level. For teachers it is about bonus incentives or mandatory retraining or the fear of losing one’s job. Negative sanctions are more prevalent than rewards. For inexperienced educators high stakes testing has many benefits including: a narrow curriculum that is focused more on the basic skills needed for success; the curriculum is aligned; teachers and students are viewed as complacent and lazy with incentives to produce or suffer punishment and shame. High stakes testing for non-educators Glass argues, provides opportunities for hostilities towards institutions that strike them as wasteful and inefficient. To researchers and educators, high stakes testing is viewed differently.

For example, pen-and-paper testing captures little of the complexities associated with school learning (Glass, 2008). Benefits resulting from the pressure of high stakes testing on teachers, students and parents are few according to Glass (2008). Any gains, though small, are produced from drill and practice exercises used by teachers to prepare their students for tests. In this framework, teachers provide little or no feedback to students about their learning (Black & Wiliam, 1998). This sort of testing has been shown not to be very purposeful for day-to-day learning because feedback was by way of right or wrong answers rather than on developing understandings of mathematical ideas that require a lengthy iterative process. It has been found to have a negative effect on students because of the dominance of frequent low-level skill testing rather than high-level conceptual development and feedback on their learning (Black, et al., 1998).

The unintended consequences of such testing are negative and serious. Other curriculum areas such as science, social studies, art, music and physical education are sacrificed so that more time is spent on test preparation activities. Under pressure, teachers and administrators are “tempted to bend the rules to avoid public shaming resulting from release of test scores to media” (p. 190). Glass cites the work of Nichols and Berliner (2007) to highlight the chaos when testing is raised too high—cheating was found to be a “standard operating procedure” (p. 191). Students who were likely to score poorly on tests were encouraged to leave school with others “held back from grades in which the testing took place and then advanced two grades to skip over the testing” (p. 191). This chaos is not isolated to the US with media reports in Australia highlighting the cheating that is occurring as a consequence of the NAPLAN testing. This prompted an inquiry into National Reporting in Australia (Senate References Committee on Education, 2010) with a number of submissions to the inquiry reporting “that increased accountability pressure may unintentionally increase the likelihood of cheating” (p. 23). The consequences of high stakes testing are disproportionate, that is, Indigenous students and those from disadvantaged backgrounds in public education are more likely to be affected and assigned to various social and academic groupings.

Student performance on traditional assessment tasks, such as pen-and-paper tests, has been shown to be used to define the students’ ability in the subject (Marshall, Wiliam, Harrison, Lee & Black, 2007; Ruthven, 2002; Watson, 2001, 2002). As a consequence, student treatment is differentiated according to their performance in the tests, with ability perceived as relatively fixed and able to be measured on the basis of test scores (Gillborn & Youdell, 2001, p. 77). Thus, ability is seen as a measurable and permanent trait, a perception that restricts the capacity for learning of many students (Ruthven, 2002; Gillborn & Youdell, 2001). Increasing the predictability of test tasks and limiting them to repetitious questions and practice items imposes further restrictions on student capacity for learning (Watson, 2001).

Hence items that have been identified as encouraging rote and superficial learning, with the giving of marks overemphasised (Marshall, et al., 2007), should not be considered reasonable grounds for determining students' knowledge and understanding of mathematics (Watson, 2001). Finally, when interpretations of formal assessment are made, ability has been found to be shaped by comparisons between and within groups of students (Ruthven, 2002).

These comparisons, focused on recognisable understanding in relation to peers, have tended to undermine many students' interest in learning, particularly those students considered less successful in mathematics (Marshall, et al., 2007). Students who perceived themselves as unable to do mathematics have been shown to give up in advance because they have learned that the only measure of success in mathematics is on a test and only a few people will get it (Ulep, 2006). Once more, what students such as these learn is that they cannot do mathematics.

Poor achievement in mathematics assessment has been found to occur in the same social groups of students, reinforcing the idea that mathematics assessment is a tool for sorting different groups of students (Berry, 2005; Bol & Berry, 2005; Walkerdine, 1998). Unfortunately, when students have been viewed as possessing the problem, they have been precluded from the very things they needed for their success in mathematics, that is, "an interest in, and curiosity about their surroundings, perseverance, and enthusiasm" (Walkerdine, 1998, p. 140). How students were perceived as a result of assessment has influenced how they identified themselves as mathematics learners, thus "forcing them into an unbreakable circle of performance" (Walkerdine, 1998, p. 146). That is, if students saw themselves as unsuccessful in mathematics they were not likely to have a strong sense of themselves as mathematics learners nor were they likely to participate in the mathematics learning of that classroom.

Achievement on tests has also been shown to be closely associated with teacher expectations of groups of students (Bol & Berry, 2005; Thompson, 2004). Differences in teachers' expectations of particular groups of students work to widen the gap between those students who can perform well on tests and those who cannot (Bol & Berry, 2005). The consequence for low achieving students is that the emphasis is placed on teaching and testing basic, low-level skills (Lubienski, 2002). Consequently, when particular groups of students do demonstrate that they are capable of achieving, they are confronted with the low expectations of the teacher, thus constraining their educational opportunities in the subject.

In summary, pen-and-paper testing has been shown to influence students' learning of mathematics significantly in the short and long term. Students do not receive purposeful feedback on their day-to-day learning nor do they find out and know where to go in terms of their mathematics learning for the future. What they do learn is that they can succeed or fail on a test. Their performance on such tests contributes to how they are treated, with ability seen as a permanent trait that is relatively fixed.

### **Summing Up: The Case against Direct Instruction-based Mathematics Education**

Six practices identified from a substantial body of research critiquing direct instruction-based mathematics have been reviewed in sequence. This review has noted the consequences of each practice for student learning in mathematics. What was also noted was that these practices do not operate in isolation. Indeed, they also need to be considered alongside other practices and agendas which have emanated from the economic and demographic circumstances that Australia is moving towards. This section draws on that evidence to evaluate the combined effect of these practices on student learning in mathematics classrooms.

In a didactic style of teaching, mathematical knowledge is transmitted to the class with minimal or no discussion. The teacher is the authoritative possessor of knowledge, and students are passive recipients of selected aspects of that knowledge. This knowledge is inculcated by drill for memorisation and the working through of graded exercises in textbooks and worksheets or board work. This use of textbooks constitutes a further authoritative source of knowledge and further inhibits active student involvement in understanding mathematics. Knowledge acquisition is thought to be ensured by pen-and-paper testing.

Testing enables students to be graded according to ability, where ability refers to their actual performance in these tests. This process of classification into degrees of success or failure supports the establishment of homogeneous ability groups, that is to say, groups of students whose tested performance is relatively comparable. This differential grouping justifies teaching mathematical knowledge ‘appropriate’ for each group and forms of teaching deemed appropriate for the capacity of each group. In this situation, while less successful students can readily fall to a lower ability group, the possibility for students to move to a higher group is limited, because they lack access to the skills and knowledge possessed by that group.

In this didactic framework, however, while teaching is pitched to the group and a common test is given to all, students work and are tested as individuals. Group interaction or student-teacher interaction is limited or non-existent. Through this ongoing individualised competitive process, winners and losers are defined and labelled. Again, since work is pitched at the level of the group, and since prescribed sets of knowledge are expected to be acquired within given periods of time, the treatment of content is likely to be superficial as the pace of teaching to a program or textbooks takes precedence over the time needed by individual students to master information.

It follows, then, that a direct instruction approach to the teaching and learning of mathematics is strongly associated with student non-participation and disengagement in mathematics. Whilst some students may learn this way, others such as Indigenous will not. Consequently, they are highly likely to disengage from the subject because the combined effects of its practices work to exclude them.

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